THE SCIENTIFIC MONTHLY

AUGUST, 1921

THE SCIENTIFIC CAREER FOR WOMEN[1]

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MAY 18 of this year witnessed a notable public event. A gathering of several thousand persons, for the most part college women, filling throughout the huge auditorium of Carnegie Hall in New York, assembled to do honor to a woman who had added a great new fact to science, and that audience was only one of the many that have assembled during the past few weeks for the same purpose. Following as it did so closely on the great war and the homage being paid to military and diplomatic leaders of the victorious nations, the occasion stands forth by contrast as signalling a new and precious order in which the triumphs of the intellect, in this instance as embodied in Madame Curie, received a merited recognition and reward. The statement is often heard that the achievements which society most honors, even in times of peace, are not the laborious ones of learning, but rather the more spectacular ones of the military profession; and it is just this perversion of values which now perhaps more than in any previous period is so disheartening. And yet the event just mentioned by no means lends support to this common point of view, but may rather be looked upon as affording a new hope and inspiring a new courage with which to meet the immeasurably important problems of society now pending.

It is perhaps also permissible to find significance in the fact that the recipient of the high honors now being conferred everywhere in this country on the discoverer of radium is a woman. In view of the discovery itself and the impetus given by it to physical, chemical, and even biological research, it may seem idle to ask the question I have so often heard asked whether there exists a scientific career for women. But there are without doubt many people who will insist that one such achievement, great as it is, can not be taken as setting aside for once and all speculation on the subject. They may continue to doubt.

[1] An address given at the commencement exercises of Bryn Mawr College, on June 2, 1921.

None the less one must admit that Madame Curie's example is a great and encouraging one for women.

The scientific career is not under all circumstances one thing. Its opportunities adapt themselves rather to different times and different types of mind. One of Leonardo da Vinci's aphorisms was that truth is always the daughter of her period. We readily distinguish two main kinds of scientific achievement or discovery so called—one of which is the outgrowth or the efflorescence of a line of investigation dealing with things predictable. The result accomplished may be new and important, but having been foreshadowed by the march of scientific events, it lacks essential novelty. For this kind of discovery, knowledge—often deep and precise—and method, but not the highest talent, are demanded. The other partakes of the accidental rather than the incidental; it never comes as a direct, but rather as an unexpected result or side issue to some line of inquiry, as something for which there is no precedent, and hence it may be easily overlooked. Discovery in this field is more certainly the mark of that individuality to which the designation genius has been applied. Perhaps the qualities which distinguish it may be aptly defined under the phrase invented by Pasteur of the "prepared mind," that is, the mind so gifted with imaginative insight and so fortified by accurate training as to be alert to perceive and quick to seize upon the novel and essential, which is turned at once to unexpected uses. It has been well said that "the discovery which has been pointed to by theory is always one of profound interest and importance, but it is usually the close and crown of a long and fruitful period; whereas the discovery which comes as a puzzled surprise usually marks a fresh epoch and opens a new chapter of science." [1]

The two kinds of achievement are discernible in the work of more than one great investigator. Thus Pasteur's laborious and ingenious studies which led first to the overthrow of the doctrine of the spontaneous generation of life, and then by way of the all important demonstration of the biological nature of the processes of fermentation and putrefaction to the secure founding of the germ origin of infectious disease, may be considered as having been previously foreshadowed; while his epochal discoveries in crystallography and in the domain of immunity were as clearly the harvests of the exceptionally brilliant and prepared mind.

The history of science contains not a few instances in which the line of investigation being carried on at a particular juncture by the master exerts a strong, often indelible and permanently directive impression upon a pupil. Thus, for example, the life work of Professor Theodore Richards in this country, which has corrected and re-

1 Lodge, Oliver, Becquerel Memorial Lecture, Journal of the Chemical Society. Transactions 1912, V. 101, II, p. 2005.

established the atomic weights of certain elements and for which he has received the highest honors in science, was begun under his first professor of chemistry. In like manner Pasteur became imbued with his master Delafosse's enthusiasm for crystal structure, considered with reference to the relation of atoms to the rotatory power upon a beam of polarized light. Hence when Pasteur obtained his first position of "preparateur" to the professor of chemistry, he set himself the task of studying crystal forms and by good chance chose the tartrates in which the phenomena he was seeking appear in the simplest form. Had he chosen other crystals, he would have had to search much longer to find the particular appearances so clear in them, but that in the end he would have succeeded may be assumed. What was constantly in Pasteur's mind at this early period was the correlation between a particular crystalline form called hemihedrism and rotatory power. This relation is determined by little faces on one-half of the edges of the crystals, the existence of which had already been noted by two chemists, the one a conscientious observer without inspiration, or as the French say *sans flamme,* and the other preoccupied with a theory which he endeavored to fit to all the facts which his studies revealed. Both thus failed to understand their significance.

Pasteur's discovery, although strictly speaking a discovery in chemistry, later had its percussion through the entire realm of science in a manner so profound that to-day, seventy years after the event, its reverberations have not yet ceased. His biographer has described it as follows:

"Pasteur noticed that the crystals of tartaric acid and the tartrates had little faces on one-half of their edges or similar angles (hemihedrism). When the crystal was placed before a glass the image that appeared could not be superposed; the comparison of the two hands was applicable to it. Pasteur thought that this aspect of the crystal might be an index of what existed within the molecules, a dissymmetry of form corresponding with molecular dissymmetry. Therefore, he reasoned the deviation to the right of the plane of polarization produced by tartrate and the optical neutrality of the paratartrate would be explained by a structural law. The first of these conclusions was confirmed, but when he came to examine the crystals of paratartrate hoping to find none of them with faces, he experienced a keen disappointment. The paratartrate was also hemihedral, but the faces of some of the crystals were inclined to the right, and those of others to the left. It then occurred to Pasteur to take up these crystals one by one and sort them carefully, putting on one side those which turned to the left, and on the other those which turned to the right. He thought that by obtaining their respective solutions in the polarizing apparatus, the two contrary hemihedral forms would give two contrary

deviations; and then by mixing together an equal number of each kind, the resulting solution would be neutral and have no action upon light. With anxious and beating heart he proceeded to the polarizing apparatus and exclaimed 'I have it.' His excitement was such that he could not look at the apparatus again; he rushed out of the laboratory, not unlike Archimedes. In the passage he met a curator and embracing him dragged him out with him into the Luxembourg gardens to explain his discovery. Many confidences had been whispered under the shade of the tall trees of those avenues, but never was there greater or more exuberant joy on a young man's face. He foresaw all the consequences of the discovery.* * * *"[2]

In like manner there can be no doubt that the discovery by Pasteur in 1880 of the artificial immunity to fowl cholera, which opened up to exploitation the wide and varied field of immunity in medicine and which is to-day one of the main achievements of medical science and is holding out still greater promises of progress in the control of disease in the future, came not as a direct incident, but rather as an accidental circumstance to the experiments on infection being pursued.

So it was also with the discovery of spontaneous radioactivity by Becquerel, to which are directly traceable the discovery of radium, and the superlative and successful efforts now being made to solve the age-long problem of the atomic constitution of matter; while Madame Curie's discovery of radium itself was not the result of a momentary inspiration on her part, but rather the consummation of a labor extending over many years, begun under conditions of great hardship and continued through obstacles and discouragements which only the great in spirit surmount.

I shall not tarry on the threshold of the story to repeat to you the details of the preliminary steps in the great career of Madame Curie, during which she did what was virtually the menial service of the Sorbonne, in order to gain the pittance of support which enabled her to enter on her scientific training. But in the end her ability was detected and she was placed in the laboratory to conduct an investigation leading to a thesis, and as it happened, under the young instructor who afterwards became her husband.

The story begins about 1860, from which time on many observations had been made on the passage of electricity through tubes from which nearly all the air had been pumped. These studies led in 1879 to the discovery of the cathode rays of Sir William Crookes and in 1895 to the discovery of X-rays by Röntgen. A year later, or to be exact, on March 7, 1896, Becquerel, who was studying the general behavior of phosphorescent bodies, examined uranium and its compounds, and discovered that these substances gave off rays which re-

2 Vallery-Radot, The Life of Pasteur, Eng. Trans. Vol. I, p. 50.

sembled the X-rays in their action on photographic plates. He also made the extremely important observation that the rays "ionized" the air about them, or converted it from an insulator to a conductor of electricity. A gold-leaf electroscope, which had been previously charged with electricity so that its two leaves diverged, was discharged, with the consequent collapse of its leaves as soon as uranium was brought near it.

The comparative ease and rapidity and metrical character of this method of examination induced Madame Curie to take as the subject of her doctorial thesis the measurement of the radioactive powers of an immense number of minerals, and so led her gradually to one of the most brilliant and striking discoveries of modern times, the whole representing a new epoch in our knowledge of atoms and therefore in physico-chemical science.[3] Her initial momentous observation related to the mineral pitchblende from which uranium is extracted, and which she found to be four or five times as radioactive as uranium itself. There was, of course, but one possible conclusion: the mineral contained another active element more powerful than uranium. At this point her husband joined in the quest and the mineral was converted into fractions, each of which was tested electroscopically. The bismuth fraction showed the presence of a powerful radioactive substance finally separated, and in honor of Madame Curie's native country called polonium; but it was the barium fraction which was most active and which finally yielded a salt of the new element called radium. Thus it was in 1902, or after four years of arduous and inspiring work, that the researches leading to the doctor's degree but also unlocking a new door in physics were brought to a temporary conclusion, and it was not until 1910, as you know, that Madame Curie actually obtained the element radium in a pure state. It is of some interest to recall that the radium salt proved 2,500,000 times as active as the uranium, the point from which her studies started.

Honors flowed in upon the discoverer. In 1903, she shared with Becquerel and her husband the Nobel prize. Then in 1911, after the isolation of pure radium, she was a second time awarded that great prize and in the words of the President of the Swedish Academy, was the first laureate to be awarded this distinction twice as "a proof of the importance which our Academy attaches to your discoveries * * *." And yet, because she was a woman, the French Institute declined to elect her to membership and the five French academies voted in favor of upholding "an immutable tradition against the election of women which it seemed eminently wise to respect."

Great discoveries never stand isolated and hence it frequently hap-

[3] Lodge, Oliver, op. cit.

pens that their main effect is to set into motion as by-products, secondary or new lines of research, the significance of which often eclipses the great discovery from which they took origin. Hence to-day it is especially in atomic physics and then in biology that the fructifying influence of the investigations in the field of radioactivity is noteworthy. It has happened that new and unimagined forces have been released suddenly for experiment and placed in the hands of the physicist and the biologist. I am not capable of giving an account of the latest experiments on atomic constitution which are being conducted with radium, and I stand filled with wonder and admiration as I read that the rapidity of the α-particle or helium atom derived from radium is about 20,000 times the speed of a rifle bullet, and that the energy of this motion is such that an ounce of helium moving with the speed of the α-particle is equivalent to 10,000 tons of solid shot projected with the velocity of 1000 meters per second. After having been stunned by this statement, I can well imagine that the charged particle is able to penetrate deeply into the structure of all atoms, built up as they are now believed to be on a plan similar to that of the solar system with a central sun or nucleus, and a system of planets in form of negative electrons, and to pass through as many as 500,000 of them before being deflected and turned back, and thus made to divulge the secrets of the electric fields near the center or nucleus of the atom.

But I may be somewhat better able to explain the present status of biological research being carried out with radioactive substances derived both from X-ray and from radium. The studies are proceeding in two directions: the one being of theoretical and the other of practical nature. The latter excite the greater interest because they are already rendering a highly useful service, as in the treatment of a certain class of cancers and in reducing excessive amounts of lymphatic tissue, even including recently the ubiquitous enlarged tonsils and adenoids. And yet, the former may in the end be of surpassing value in that they will serve to explain the manner in which radioactivity brings about the biological effects noted, and the means by which those which are desirable and useful may be intensified and those which are undesirable, because harmful, may be minimized or avoided altogether. Already we have learned that the radiations act quite directly on the lymphoid organs and, according to the amount or dosage employed, either stimulate to over-activity or bring about destruction; while the action on cancerous tissue is more indirect and bound up, in part at least, with the impression made upon the lymphatic system. But what I especially desire to emphasize is the connection which this class of investigations has established between the physicist and the biologist. It happens that neither alone can compass the entire field; the one is

too little a physicist, the other too little a biologist in order to manage on the one hand the rays and on the other the tissues. Together they make a working team, and already a new division of research in biophysics is beginning to appear to herald that co-operation in scientific research which is to-day one of the necessities as it is the harbinger of progress.

It should now be apparent how impossible it is for mere accident to yield a discovery in science. Whether the investigator move in the lower or the upper realm of experiment and observation, there are demanded as a minimum, knowledge of fact and familiarity with method, with which not even the most fortunately circumstanced are naturally endowed. Environment and possibly heredity also play parts, sometimes highly important parts, in giving the impulsion which leads into scientific careers and accomplishment. Moreover it is a mistaken notion to suppose that the scientific intelligence can only be and always is trained in school or college as ordinarily defined. The history of science indeed contains illuminating pages recounting the successes of men without any real formal education who have surmounted all difficulties and written their names large in its story. Such a man was Michael Faraday, of whom it has been said that of all the men who have spent their lives in the search for experimental discoveries, no one has ever approached him in the number, variety, or the importance of the new facts disclosed by his labors; and yet he was led into the pursuit of science by reading the books which passed through his hands while he was a bookbinder's apprentice.

Hitherto it has been men rather than women who have chosen the scientific career, and up to now the shining names on the banner of science are those of men and not of women. It could not have been otherwise; but now that the doors of opportunity have been thrown widely open to women, one may expect that many more will pass their portals and enter upon the career of science. Already they are feeling its lure and perceiving their aptitudes. But the lesson can not be enforced too emphatically that whether science is entered by the front door of the college or by the back door of the amateur or apprentice, in the end the material and means of science must be mastered if the votary aspires to enter paths never trodden before. To acquire that mastery to-day is no small undertaking, since the subject matter of the sciences is so voluminous and the methods often so intricate and precise. But there is nothing in my opinion in either which the trained intelligence can not grasp and the trained senses execute.

I do not recognize a line of demarcation between the sciences which men on the one hand and women on the other should choose as a career. With women as with men what should count are taste and aptitude and opportunity. It is common experience to find that a man

is directed or diverted into a given scientific field by accidental circumstances: a book falling into his hands at a critical moment; a particularly inspiring teacher who, like radium, transmutes his pupils as that does the elements; a region favorable say to geological study; a parent or other person with whom the impressionable child chances to be thrown. Once fairly launched on a career, the native ability determines the rest, just what particular road is followed and how far the traveller is carried along the road.

Even earlier influences may come to play a deciding part in directing the will and bent of the child. It does not take special insight to discern the differences in the intellectual atmosphere surrounding boys and girls in the home. While the girl is complacently occupied with dolls and miniature dressmaking and millinery, the boy's imagination is being excited by mechanical toys which his aroused interest impels him to destroy, in order that the inner mechanism may be laid bare. This is the period at which a youthful Galileo and Newton will construct windmills and water clocks, and a future Herschel, aided perhaps by another sister Carolin, will fashion some sort of optical device, the forerunner of his first telescope.

Then also custom and habit will determine that the father himself on science bent will endeavor to communicate his taste to his son rather than to his daughter. It took three generations of the Becquerel family, all concerned with the study of light phenomena, to produce the discoverer of spontaneous radioactivity. Charles Darwin's son and now his grandson are pursuing at Cambridge with distinction the related fields of mathematical astronomy and mathematical physics. Perkins, the discoverer when only seventeen years of age of the aniline dyes, has been followed by a son, the eminent professor of chemistry at Oxford; and father and son of the Bragg family have recently shared the Nobel prize for discoveries in physics.

The examples might be multiplied in which because of custom the boy, but not the girl, has been subjected to influences extending over many years calculated to prepare or to lead him, if only insensibly, into the paths of science. Moreover, the boy has other advantages to guide and spur him on: once launched on a scientific pursuit, he looks forward to a life's career and indulges the hope, if not the expectation, of being attended by some good woman. Now women have not yet been offered anything approaching a like opportunity to that put before men. The scientific career means too often for them, if consistently pursued, the denial of domestic companionships and compensations which men easily win and enjoy. In how far this condition alone will operate to bar women from the higher pursuits and greater rewards of a scientific career only experience can show. But as one who would write himself down a lover of opportunity for women, I wish to ex-

press the hope that the difficulty may not prove insurmountable. Already in this country and in two fields of which I have personal knowledge, Doctor Florence Sabin of the Johns Hopkins Medical School and Doctor Louise Pearce of the Rockefeller Institute for Medical Research have made themselves authorities in their respective branches of medical science. The latter has recently carried out a difficult mission to the Belgian Congo in connection with African sleeping sickness, such as formerly would have been entrusted to a man.

A last word. I have not spoken of the rewards of the scientific career. As with other intellectual pursuits, they are to be reckoned only partly in the coin of the country. Science is now so far developed in the United States that in college, research institution, or industry a competence can readily enough be found. In the end the greater reward will be an inner satisfaction and happiness arising out of a conscious mastery of a field of human endeavor. But for this there must be a real mastery such as comes not easily but only after a period of years and as a result of a seriousness of purpose and a concentration of effort which alone devotion to a high cause will insure.